Global Assessment of Hydrogen-Based Technologies

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Objectives

- Synthesize the state-of-practice for four potential hydrogen-based vehicle technologies.
- Compare performance, emissions, and fueling characteristics of the four technologies (instrumentation).
- Compare the four technologies in light of their potential role in a full-scale deployment.
- Assess hydrogen infrastructure needs to support deployment (at local, regional, and national levels).
- Offer education and training programs to increase the knowledge of the new technologies.
- Increase the awareness of the new technologies through various mechanisms such as promotional materials for public media, a web-site, college programs, and a Hydrogen Fair in the southeastern U.S. to demonstrate the various vehicle technologies, pumping stations, hydrogen storage, safety issues, etc.

Technical Barriers

This project addresses the following technical barriers from the Technology Validation section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year R,D&D Plan:

- A. Vehicles
- C. Hydrogen Refueling Infrastructure

Approach

- Evaluate candidate hydrogen-fueled vehicles for near and long-term use in the southeastern U.S. in terms of their efficiency, performance, and emissions. Four types of hydrogen-fueled vehicles are being assessed: hythane-fueled internal combustion engines (ICEs), hydrogen-fueled ICEs, hydrogen-fueled hybrid electric propulsion vehicles (HEV), and direct hydrogen fuel cells.
- Conduct rigorous performance and exhaust emissions testing of hydrogen technologies:
  1. ICE vehicles fueled with hydrogen-compressed natural gas (CNG) fuel mixtures (15-50% hydrogen, 50-85% CNG),
  2. ICE vehicles fueled with pure hydrogen, and
  3. Hydrogen-powered fuel cell vehicles.
- Estimate resource requirements and costs for the infrastructure needed to deliver new fuels to advanced technology vehicles. Argonne's Natural gas Infrastructure Component Cost (NICC) model will be applied to the southeastern U.S., specifically the Birmingham/Atlanta region, to develop cost

estimates and define additional hydrogen pathways. In addition, practical considerations in the design and development of fuel delivery facilities will be investigated.
- Evaluate the ability of the vehicle technologies described previously to contribute to improved air quality in the Southeast, with special attention given to the Atlanta metropolitan area. Argonne's Air Quality Credits (AIRCRED) and Greenhouse Gas Energy and Emissions in Transportation (GREET) models will be used to assess impacts of a large-scale deployment on pollution emissions.
- Determine the feasibility of using hydrogen fuel cell technologies for electric power generation. The potential to conduct an actual demonstration in the greater Birmingham, Alabama, area in such electric power applications as recreation parks, student housing facilities, or heavy industrial applications will be assessed to identify possible deployment locations and potential benefits. Measurements will be made to determine if the fuel cell technology will lead to pollution reduction and air quality enhancement, especially in an ozone non-attainment area such as Birmingham.
- Establish the Southeast Hydrogen Technology Consortium (SHTC) to examine ways to establish a hydrogen infrastructure in the Southeast and enhance the infrastructure and application of the technology. The members will be experts in the field and representatives of different areas and sectors with interest in hydrogen technologies for both power generation and transportation.

Accomplishments

- A Ford F-150 was tested at Argonne National Laboratory using the dynamometer facility in their Transportation Technology R&D Center during May, 2003. The Ford F-150 was run on a fuel mixture (hythane) of ~50% hydrogen and ~50% compressed natural gas. Emissions data were collected for carbon monoxide (CO), carbon dioxide (CO_2), total hydrocarbons (THC), nitrous oxides (NO_x), and particulate matter. The equivalent miles per gallon fuel consumption was also monitored. Results were obtained using cold starts, hot starts, standard vehicle testing, and highway testing. The University of Alabama at Birmingham (UAB) compared the results with typical (high and low) emissions performance for CO, THC, and NO_x, for light-duty and heavy-duty vehicles. The results indicated that using the 50% hythane fuel mixture, reductions in CO, THC, and NO_x exceeded 97%, 95%, and 94%, respectively, indicating that the emissions were reduced by more than an order of magnitude.
- The UAB study team has received training on use of the PSAT vehicle simulation model to compare the efficiency and emissions of hydrogen-fueled vehicles with conventional internal combustion vehicles.
- Data has been collected for inputs to the regional AirCred model.

Future Directions

- Evaluate additional test vehicles (hydrogen ICE and hydrogen fuel cell) for performance and emissions.
- Simulate and compare hydrogen-fueled vehicles to conventional ICEs.
- Use results of vehicle tests and simulations to evaluate potential impacts of a hydrogen vehicle deployment.
- Investigate infrastructure requirements for a hydrogen vehicle deployment, including potential hydrogen producers and transport mechanisms. Investigate codes and standards related to hydrogen fueling stations.

Introduction

Hydrogen-fueled vehicles hold the potential to reduce the emissions of pollutants and greenhouse gases currently associated with conventional gasoline- and diesel-fueled vehicles. Hydrogen-based vehicle technologies, however, are still in the very early stages of development, and their performance characteristics compared to conventional internal combustion engines (ICEs) are not well established. There are currently several promising hydrogen technologies available, but their potential for widespread deployment requires further evaluation. In the near term, hydrogen-fueled internal combustion engines (similar to conventional engines but modified to run on hydrogen or hydrogen-CNG blends) may prove to be the most immediately feasible technology. Another promising near-term technology are hydrogen-fueled hybrid electric vehicles, similar to the gasoline-powered hybrid electric vehicles already available, but with the gasoline motor replaced by a hydrogen-fueled motor. Hydrogen fuel cell vehicles may ultimately provide the lowest emissions of any hydrogen technology, but their development is also the most complex, and they are therefore generally considered a longer term option.

Any assessment of the potential for large-scale deployment of these hydrogen technologies must be based on measured vehicle performance characteristics, not simply estimates. Only with realistic emissions and vehicle performance measures can we develop reasonable estimates of what impacts a large-scale deployment would have on air quality and which vehicle technologies offer the most promising near-term and long-term benefits. Such an assessment will also need to consider the cost of the infrastructure required to fuel and maintain these vehicles. Large fleets of hydrogen vehicles will require hydrogen production plants, transport systems, and fueling stations that do not yet exist and whose costs are not yet known. The purpose of this study is to evaluate the performance characteristics of various hydrogen vehicle technologies, identify the most promising near- and long-term technologies, and fully understand the infrastructure that a large-scale deployment will require.

Approach

The research will follow two primary tracks: (1) an evaluation of the performance characteristics of four hydrogen-fueled vehicle technologies, and (2) an investigation of hydrogen infrastructure requirements. The study will examine four promising hydrogen vehicle technologies: hythane-fueled ICE vehicles, hydrogen-fueled ICE vehicles, hydrogen-fueled hybrid electric vehicles, and hydrogen fuel cell vehicles. The performance and emission characteristics of each type of vehicle will be measured at the Argonne National Laboratory test facility. The results of these tests will be incorporated into the PSAT vehicle simulation model and used to further compare the performance and emissions characteristics of each vehicle technology to conventional gasoline- and diesel-powered vehicles. The PSAT model outputs will then be input into the AirCred and GREET models to estimate the air quality impacts of a large-scale deployment of hydrogen vehicles in thes United States.

The second thrust of the research will be to investigate the infrastructure that such a large-scale vehicle deployment would require. Current hydrogen production and production capacity in the southeastern United States will be assessed, as will the production of fuels and resources required to produce hydrogen (CNG, coal, methane) and the

Figure 1. Ford F-150 Truck on Dynamometer at Argonne National Laboratory

transport systems (truck, rail, and pipeline) currently available to convey them. Based on the results from earlier portions of the study, estimates of the hydrogen demand for a large-scale vehicle deployment will be developed, and the cost of the additional infrastructure required to meet this demand will be assessed. The study will also examine the practical considerations involved in constructing and supplying hydrogen fueling stations in an urban environment.

Results

The study is currently getting underway. Results and conclusions will be provided as they become available.

FY 2003 Publications/Presentations

1. Presentation by Fouad H. Fouad to the Southern Research Institute at the Department of Energy Atlanta Regional Office on June 16, 2003.